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COST ESTIMATING RELATIONSHIP FOR THEORETICAL FIRST UNIT COST FO--ETC(U)
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LEVEL II

(2)

(6) COST ESTIMATING RELATIONSHIP FOR THEORETICAL FIRST UNIT COST FOR MEDIUM BORE GUNS (10 - 40MM),

(14) DCA-R-44

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(11) DEC[redacted]1976

(12) 12

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1. GENERAL.

a. Title. Cost Estimating Relationships for Theoretical First Unit Cost for Medium Bore Guns (10 - 40mm).

b. Summary. This report contains the results of an effort to collect data and develop a Cost Estimating Relationship (CER) to be used for predicting production costs for medium bore guns. The CER is based on two independent variables; size of the bore and number of barrels. Statistical attributes of the CER include a multiple correlation coefficient of 0.9969 and an index of determination of 0.9939. The data base contains seven data points representing guns with bore sizes that range from 7.62 to 40 millimeters with one to six barrels. The costs have been normalized to FY 77 dollars.

c. Approach.

(1) The data base used for developing a CER by Mr. Jerry Kalal of ARMCOM (formally WECOM) in 1973 was used as a starting point for data collection.[1] Four data points were used from his data base and cost data from three new weapon systems were added.

(2) For each gun system in the data base, theoretical first unit cost and the corresponding slope of the learning curve were developed from basic lot data.

(3) Scatter diagrams were developed for potential independent variables. Three variables (gun weight, bore size, and number of barrels) were selected for further analysis.

(4) Using the General Electric Statistical System (STATSYST)[2], potential CER curves were generated and evaluated.

(5) Gun weight was eliminated because there was high correlation between it and the bore size. Consequently, a basic assumption that independent variables are in fact independent would have to be violated.

[1]Kalal, Gerald, "Cost Estimating Relationships for Machine Gun, Theoretical First Unit Cost," Cost Analysis Division HQ, WECOM, AMSWE-CPE 73-2.

[2]"Statistical Analysis System (STATSYST)" Information Services Business Division, General Electric, December 1971 (Revised December 1975).

(6) Using bore size and number of barrels a series of curves were developed and the CERs with high correlation were analyzed for integrity, logic and statistical properties.

2. MATHEMATICAL FORM. The CER which exhibits the best qualities from the above approach is

$$Y = 1686(X_1) + 1326(X_2)$$

where

Y = Theoretical First Unit in FY 77 Dollars

X_1 = Bore Size in Millimeters

X_2 = Number of Barrels

3. STATISTICS. Table 1 contains a summary of the statistics for the CER. The F Statistic Value of 406.7 represents that the null hypothesis (that the slope of the plane is 0) can be rejected with 100.0% confidence. The high multiple correlation coefficient of 0.9969 is also noteworthy.

4. DATA ANALYSIS.

a. Data Base. Table 2 shows the seven points in the data base. Costs have been normalized to FY 77 $ using the Shift Factors in Annex C.

b. Data Source. All data was taken from the Cost Analysis Division files of the ARMCOM Comptroller Officer. The data was extracted from contracts which were executed by the ARMCOM P&P Directorate.

c. Data Description. The costs used in the data base are contractor production costs and include cost of materiel and labor for manufacturing, engineering support, quality assurance, consumable tooling, and plant overhead. The costs do not include profit and G&A.

d. The recommended learning curve slope to be used with this CER is 89.0% which is the average of the slopes in the data base.

e. A brief description of each point in the data base is contained in Annex B.

TABLE 1

SUMMARY STATISTICS

EQUATION

$Y = 1686(X_1) + 1321(X_2)$

where

Y = Theoretical First Unit Cost in FY 77 $
X_1 = Bore Size in Millimeters
X_2 = Number of Barrels

STATISTICS

F Value Significance (100.0%)	407.7
Multiple Correlation Coefficient	0.9969
Index of Determination	0.9939
Adjusted Index of Determination	0.9914
Standard Error of Estimate	3,797

CORRELATION MATRIX

	COST	BARRELS	BORE
Cost	1.000	0.9927	0.6445
Barrels	0.9927	1.000	0.5731
Bore	0.6445	0.5731	1.000

CONFIDENCE INTERVALS FOR REGRESSION COEFFICIENT

CONFIDENCE LEVEL	X_1 COEFFICIENT	X_2 COEFFICIENT
90%	(1530;1842)	(313;2339)
95%	(1487;1885)	(34;2618)

TABLE 2
GUN DATA BASE*

NOMENCLATURE	DESCRIPTION	BORE SIZE (MM)	NO. OF BARRELS	FIRST UNIT+ COST (77 $)	LEARNING SLOPE (%)
M73	LIGHT MACHINE GUN	7.62	1	13,538	90
M134	MINI-GUN	7.62	6	23,488	88
M85	50 CAL MACHINE GUN	12.7	1	21,961	90
XM197	MOUNTED ON AH-1J FOR MARINES	20	3	40,674	84
M61A1	VULCAN SERIES	20	6	37,901	89
XM140	DEVELOPED FOR CHEYENNE	30	1	46,914	91
M2A1	DUSTER	40	1	72,748	90

*ALL WEAPONS ARE:

A. SINGLE FEED

B. VEHICLE MOUNTED W/RECOIL ADAPTERS

+DOES NOT INCLUDE PROFIT OR G&A

ANNEX A

SAMPLE CALCULATION

1. In order to demonstrate the proper way to use this CER, a sample calculation is listed below:

a. Problem. Estimate the cost of a 30mm gun with three barrels. Assume a one lot buy of 300 guns.

b. Calculation. Using the CER

$$Y = 1686(X_1) + 1326(X_2)$$

where

X_1 = Bore Size in Millimeters = 30

X_2 = Number of Barrels = 3

therefore

$$Y = 1686(30) + 1326(3) = \$54,558$$

which is the Theoretical First Unit Cost in FY 77 $.

2. In order to calculate the Average Unit Cost of a lot of 300, utilize the following formula:

$$\text{Avg Unit Cost} = Y \frac{\left[(M_1 - 0.5)^{1+b} - (M_2 - 0.5)^{1+b}\right]}{\text{Lot Size } (1+b)}$$

where

M_1 = Last item in lot = 300

M_2 = First item in lot = 1

b = ln .89/ln2 = -0.1681 (89.0% is slope of the learning curve)

1 + b = 0.8319

Y = First Unit Cost = $54,558

Lot Size = 300

$$\text{Avg Unit Cost} = \frac{54{,}558(299.5^{0.8319} - 0.5^{0.8319})}{300(0.8319)}$$

$$= \$24{,}983$$

$$\text{Cost of the lot} = 300(24{,}983) = \$7{,}494{,}900$$

Recall that the cost data points do not include profit and G&A, therefore a production cost estimate would have to be increased. Assume 10% profit and 7% G&A. Therefore the cost of the lot is now

$$(1.18)(7{,}494{,}900) = \$8{,}843{,}982 \text{ (FY 77 \$)}$$

ANNEX B

DATA BASE DESCRIPTION

This Annex contains a brief narrative explaining each gun in the data base. Also the pertinent facts concerning cost, quantities, lots and contracts are included so that the reader fully understands the data base that is underpinning the CER.

1. M-73, Light Machine Gun.

a. The M-73 is a 7.62 millimeter, single barrel, light weight (29 lbs), air cooled weapon that is used primarily as a coaxial gun on tanks. It employs a disintegrating metallic link belt feed for either the left or right side. The M-73 has a short receiver and is recoil operated with a gas assist to boost recoil. The gun is fired from the open bolt position and has a quick change barrel.

b. M-73 Cost Data. The data used in the data base was based on three lots with a total buy of 3,130. The contracts were with General Electric and ran from FY 67 through FY 69. The calculated First Unit Cost is $13,538 in FY 77 $. A 90% slope for the learning curve was estimated by General Electric. The reason an assumption of 90% was used rather than actual data is that extensive Government Furnished Materiel was provided to GE at no cost when the Government closed down the Springfield Armory. Consequently, the actual cost data could not be used to determine a learning curve slope.

2. M-134, Mini-Gun.

a. The M-134 is a 7.62mm mini-gun which is light weight and designed specifically to fill the need for small caliber weapon for light aircraft and helicopters. The gun is externally powered and motor driven which cause the six barrels to be rotated and allows a rate of fire of up to 6000 shots per minute. The gun has been used extensively on practically all types of Army helicopters.

b. M-134 Cost Data. The data for the M-134 is based on 11 lots for a total buy of 9,502. The contracts were with General Electric and ran from FY 66 through FY 71. Using the basic lot data the developed First Unit Cost is 23,488 (FY 77 $). The estimated slope of the learning curve as estimated from the 11 lots is 88%.

3. M-85, 50 Caliber Machine Gun.

a. The 50 caliber machine gun is a recoil operated air cooled weapon which was specifically designed to be vehicle mounted (either tank or

personnel carrier). The weapon has simple design which allows rapid field stripping and the single barrel can be changed in five seconds by experienced personnel.

b. M-85 Cost Data. The cost data in the data base was based on three lots and a total buy of 2,098. The contracts were with General Electric and ran from FY 67 through FY 69. The cost data reflects a Theoretical First Unit Cost of $21,961 with an estimated learning curve slope of 90%.

4. XM-197.

a. The XM-197 20mm gun is a three barrel, externally powered, light weighted version of the proven M61A1 vulcan gun. It is designed for applications requiring a light weight highly reliable gun capable of firing at rates of up to 1500 shots per minute. The XM-197 is the primary armament on the AH-1J marine helicopter. Included with the gun are two specially designed recoil adapters. The gun operation is based on the externally powered rotating cluster of barrels. Each barrel has its own bolt which sequentially rams, locks, fires, unlocks and extracts rounds during one revolution of the barrel cluster.

b. XM-197 Cost Data. The cost data in the data base was based on four lots and a total buy of 134. The calculated First Unit Cost is $40,674 (FY 77 $) and the learning curve slope is 84.5%. The contractor was General Electric.

5. M61A1.

a. The M61A1 20mm Vulcan is an externally powered gun having a cluster of six barrels capable of firing at rates of up to 6000 shots per minute. The gun is basically a Gatling type mechanism. Each of the gun's six barrels fires only once during each revolution of the gun barrel cluster. The M61A1 is used in a variety of employments. Its primary use in the Army is the Vulcan Air Defense System which is deployed at Division.

b. M61A1 Cost Data. The cost data reflects the Governments purchase of 7470 Vulcans over the years 1968 - 1974. The contractor is General Electric. The calculated First Unit Cost is $37,901.

6. XM-140.

a. The XM-140 is a single-barrel automatic 30mm weapon system which was developed by Philco-Ford for the Army's Cheyenne Helicopter. The gun was fully developed and approximately 100 prototypes were built before the Cheyenne program was terminated.

b. XM-140 Cost Data. The XM-140 cost data point reflects an estimate of production cost for a quantity of 500. The estimate was developed by Government cost personnel who were at the Philco-Ford plant and extensively reviewed the contractor's budgetary and planning estimates for the gun. The contract for the XM-140 guns was in the negotiation phase when the Cheyenne program was terminated.

7. M2A1.

a. The M2A1 is a dual automatic 40mm gun which is referred to as the Duster. This gun is currently being phased out of the active Army inventory. The cannon is intended primarily for anti-aircraft fire in the range between the 90mm and cal 50 machine gun. It can also be used against ground targets.

b. M2A1 Cost Data. The contracts to build this gun were executed back in the early 1950's. The personnel at Watervliet and ARMCOM maintain that cost data point is valid although they recognize that they do not have the primary source (contract) data.

ANNEX C

HISTORICAL MULTIPLIERS*

FY	RDTE	WTCV	AMMO	OPA	OMA
45	3.564	3.503	3.427	3.395	4.144
46	3.182	3.060	3.031	2.994	3.712
47	2.765	2.704	2.715	2.702	3.164
48	2.520	2.542	2.560	2.575	2.831
49	2.448	2.522	2.535	2.566	2.738
50	2.430	2.417	2.450	2.462	2.714
51	2.323	2.412	2.438	2.477	2.582
52	2.259	2.409	2.427	2.450	2.633
53	2.224	2.399	2.399	2.422	2.626
54	2.197	2.301	2.302	2.306	2.606
55	2.157	2.194	2.198	2.208	2.464
56	2.094	2.080	2.096	2.105	2.341
57	2.024	2.027	2.046	2.068	2.220
58	1.974	1.996	2.018	2.039	2.187
59	1.940	1.991	2.012	2.039	2.158
60	1.910	1.974	1.998	2.021	2.156
61	1.884	1.977	1.997	2.025	2.135
62	1.862	1.974	1.992	2.015	2.150
63	1.837	1.959	1.973	1.995	2.143
64	1.807	1.923	1.937	1.954	2.121
65	1.773	1.885	1.896	1.913	2.075
66	1.725	1.842	1.851	1.865	2.036
67	1.666	1.791	1.796	1.807	1.989
68	1.601	1.731	1.732	1.741	1.934
69	1.529	1.656	1.658	1.693	1.863
70	1.454	1.571	1.574	1.577	1.773
71	1.389	1.498	1.492	1.494	1.686
72	1.330	1.419	1.402	1.399	1.630
73	1.255	1.307	1.290	1.282	1.515
74	1.154	1.162	1.157	1.146	1.270
75	1.062	1.071	1.068	1.068	1.077
76	1.000	1.000	1.000	1.000	1.000

Data Source: Mr. John Beach
OASD(C):DASD(P/B)PS
28 Jan 76

WTCV: 1975 → 1977 1.194
1973 → 1977 1.457

*Used by ARMCOM Comptroller


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